Use of higher-order Legendre polynomials in node-dependent kinematic shell elements

Use of higher-order Legendre polynomials in node-dependent kinematic shell elements

Guohong Li*, Erasmo Carrera*, Alberto Garcia de Miguel*, Alfonso Pagani*, Enrico Zappino*
**MUL*^{2} *Group, Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Torino, Italy*
E-mail: guohong.li@polito.it

Keywords: node-dependent kinematics, refined shell models, Carrera Unified Formulation.

Towards improving the numerical efficiency of shell finite element (FE) models, hierarchical higher-order Legendre polynomials are used as shape functions in combination with node-dependent kinematics (NDK). The p-refinement with Legendre polynomials enhances the capabilities of shell elements in capturing the deformations with faster convergence [1]. By treating the polynomial degree of the shape functions as an independent input parameter, a series of FE models can be constructed on one set of mesh, which simplifies the simulation procedure. On the other hand, refined kinematics improves the accuracy of shell models for the analysis of laminated thin-walled and thick structures. Carrera Unified Formulation (CUF) permits the derivation of refined shell theories in a compact manner [2]. CUF also facilitates the implementation of various theories in either Equivalent Single Layer (ESL) framework or Layer-wise (LW) approach. Derived from CUF, NDK proves to be a convenient method to define kinematic refinement local to the chosen nodes. Through NDK, a variety of kinematic theories attached to different nodes can coexist in an FE model with no addition coupling nor superposition technique. By applying refined kinematic assumptions on the desired nodes in the domain of interest, while leaving the non-critical region modeled with lower-order but adequate theories, the solution costs can be reduced significantly without losing accuracy. In the present work, the aforementioned refinement schemes, namely the enrichment of shape functions on the elementary level and kinematic refinement on the nodal level, are used in conjunction to improve the efficiency of shell models. The efficacy of the proposed approach is investigated through numerical studies on laminated shell structures. The computational efficiency of the FE models is assessed by comparing the accuracy against the computational costs. The remedy for locking effects is discussed.

References

[1] *Szabó, B., Düster, A., Rank, E., "The p-Version of the Finite Element Method", Wiley Online Library (2004).*

[2] *Carrera, E., Cinefra, M., Petrolo, M., Zappino, E., Finite element analysis of structures through Unified Formulation, John Wiley & Sons (2014).*